



CO₂ Sequestration Options for California

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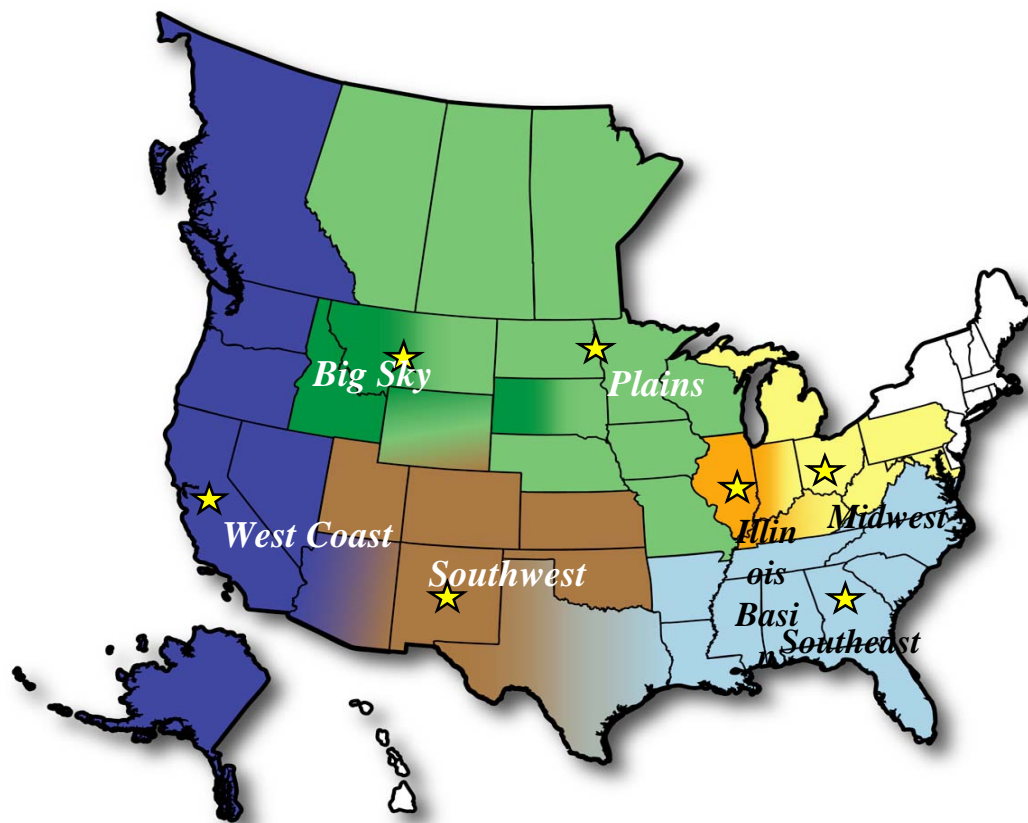


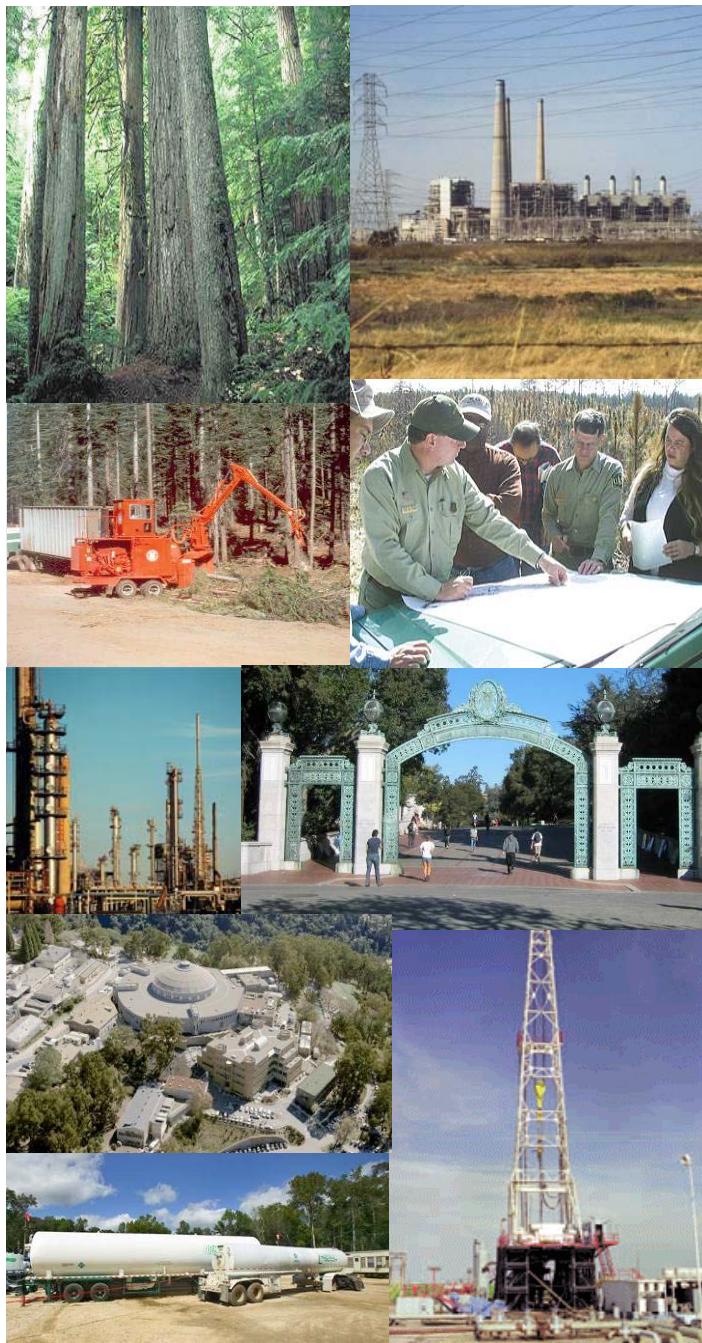
Outline

- What is WESTCARB?
- Regional-scale assessment of sequestration opportunities
- Focus on field pilot studies
- Summary

WESTCARB Is One of Seven DOE Regional Carbon Sequestration Partnerships

- Opportunities for terrestrial and geologic CO₂ storage are being evaluated
- DOE program represents 40 states, 4 provinces, and over 240 organizations
- Phase I (complete): focus on regional assessments
- Phase II (under way): focus on pilot studies
- Phase III (coming): pre-commercial geologic field test





WESTCARB Features Strong and Diverse Set of Partners; Robust Cost Share

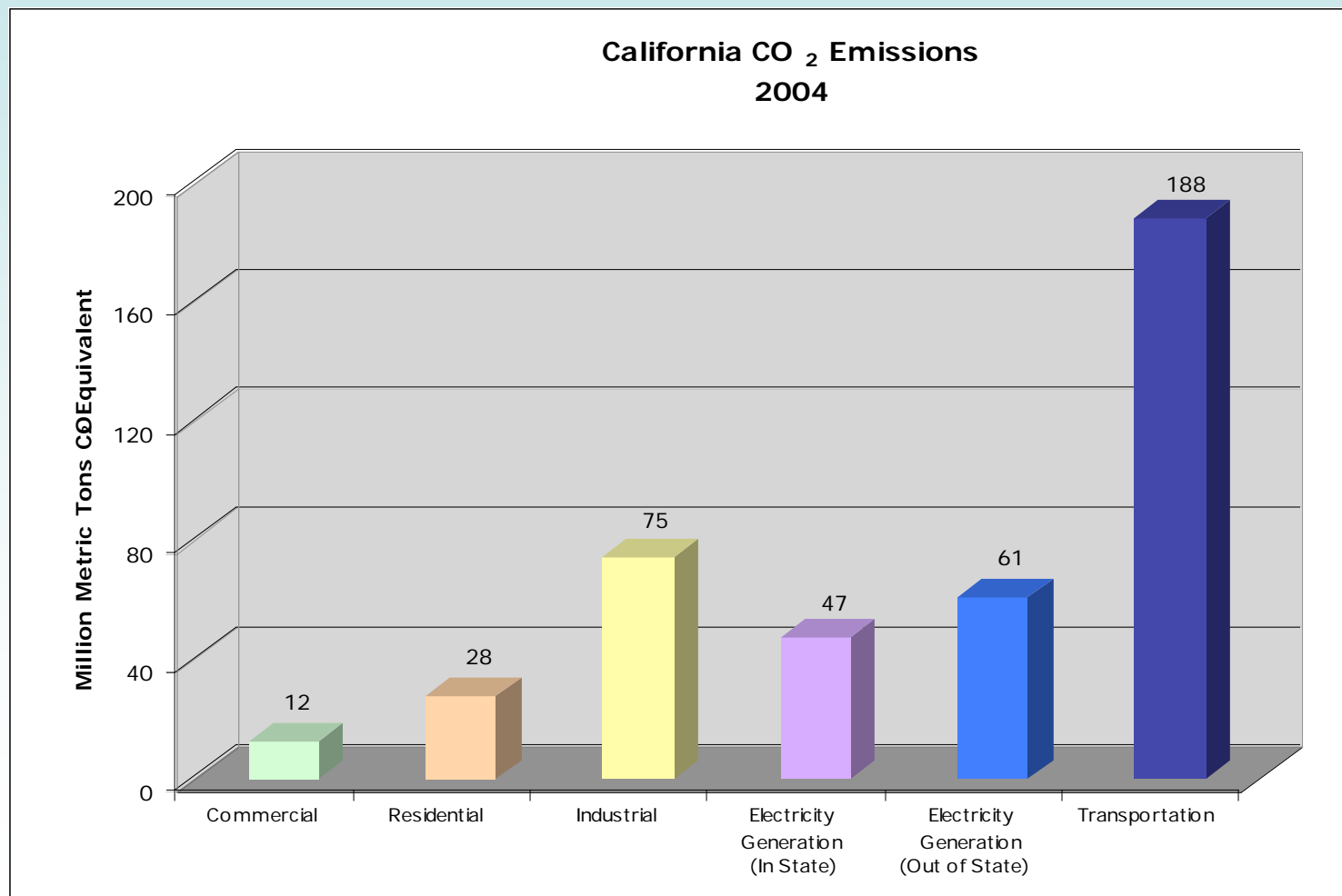
- More than 70 organizations comprising:
 - Resource management and environmental protection agencies
 - National laboratories and research institutions
 - Forest-product and ranching interests
 - Conservation and environmental nonprofits
 - Climate project standards organizations
 - Energy and pipeline companies
 - Colleges and universities
 - Trade associations and policy coordinating bodies
- Represents world-class technical expertise
- Led by California Energy Commission

Terrestrial and Geologic Sequestration Are Both Options

- Terrestrial: Sequestration of carbon by natural processes in forests, plants, and soil; CO₂ source independent
- Geologic: Sequestration of CO₂ in deep saline formations, oil and gas reservoirs, and coal-beds; requires industrial processes to capture at source and inject on-site or transport via pipeline
- Technology for both options is available and being implemented



California CO₂ Emissions by Sector

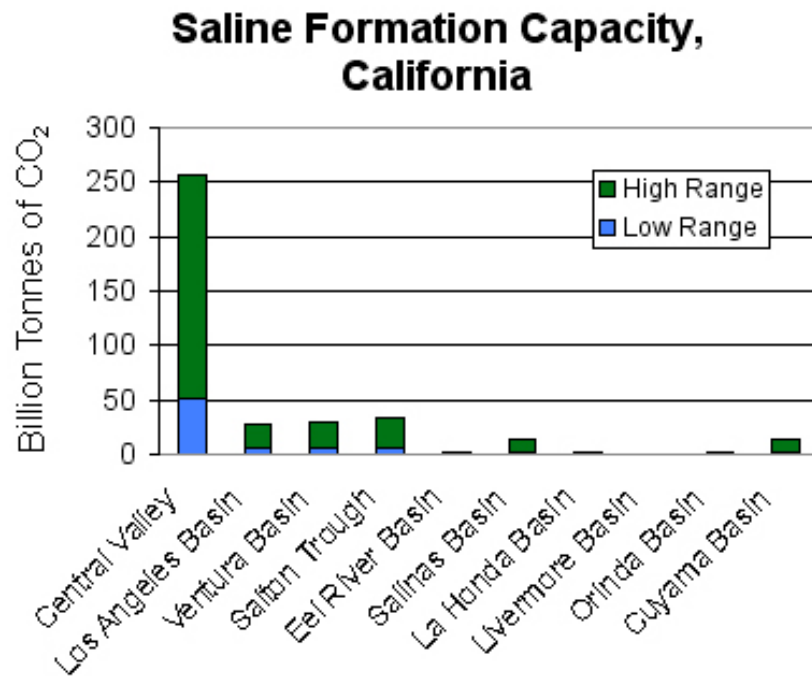


Source: U.S. EPA

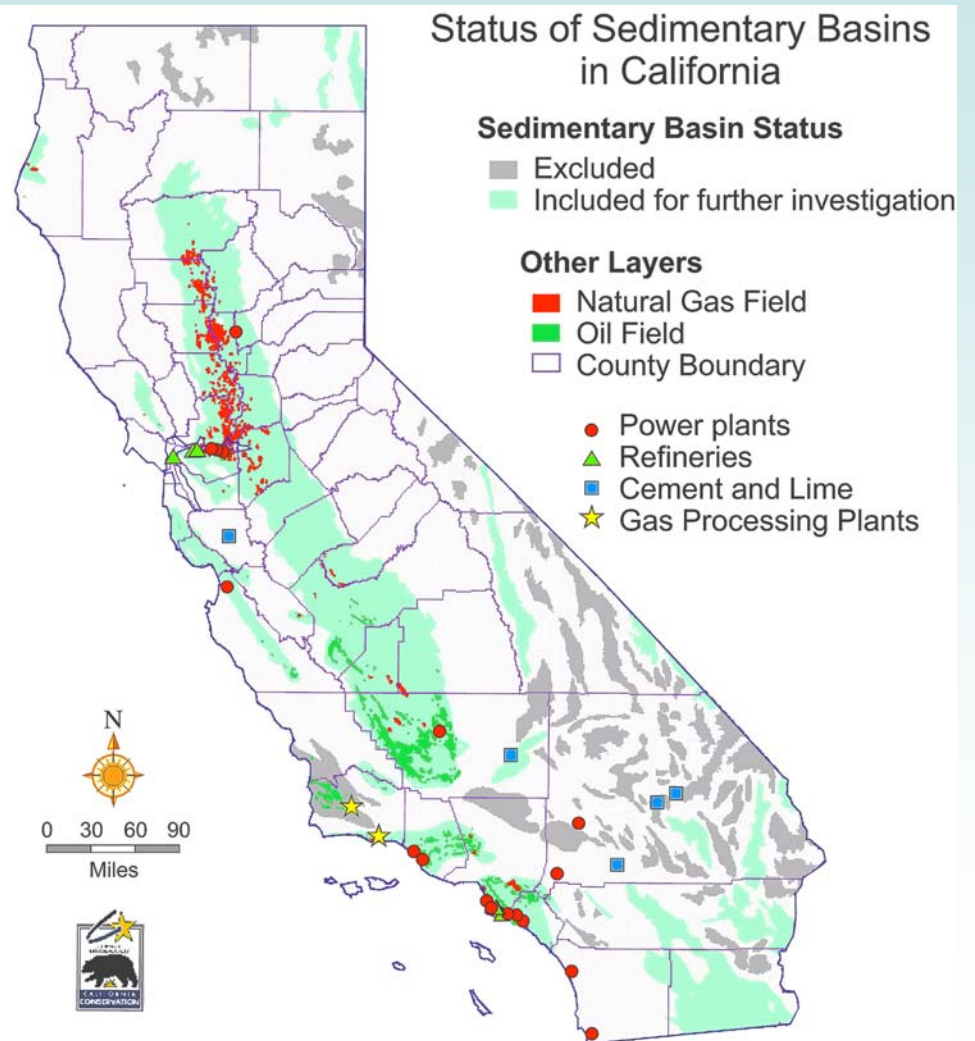
Primary Geologic Storage Options for California

- Oil and gas reservoirs
 - Storage with Enhanced Oil Recovery (EOR) or Enhanced Gas Recovery (EGR)
 - Storage only
- Saline formations
 - Storage only

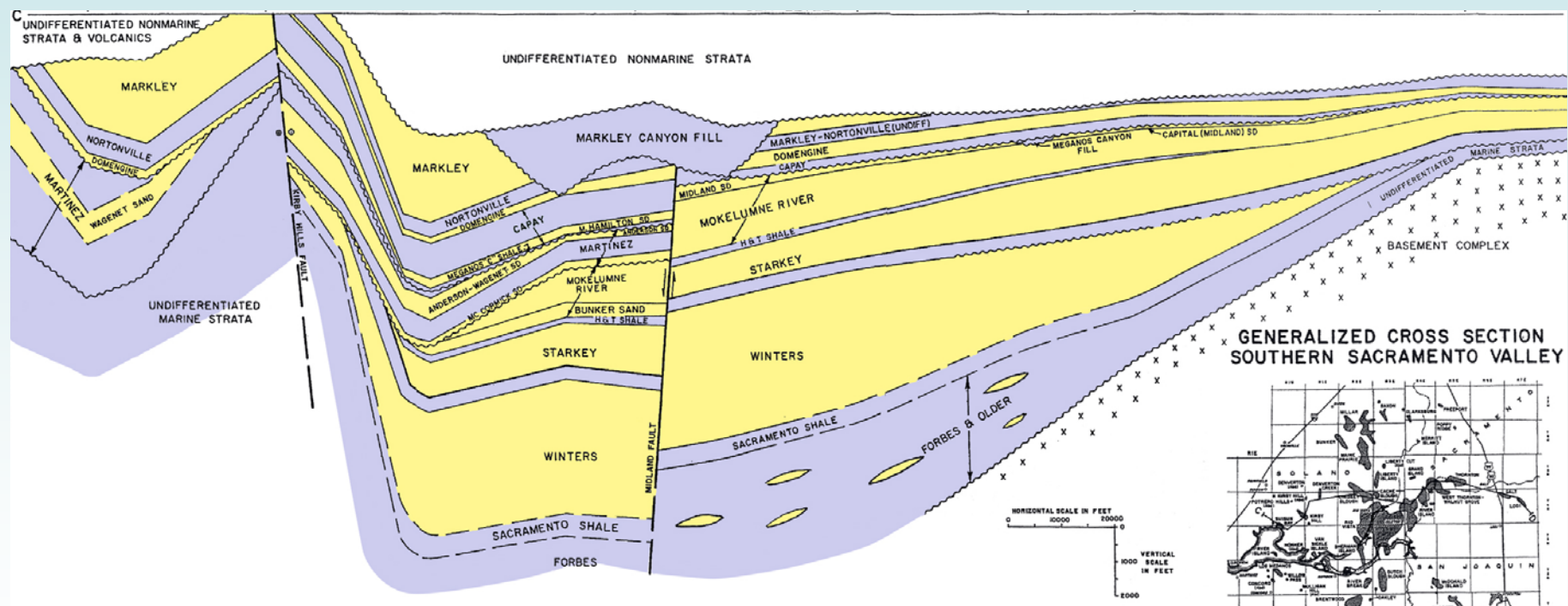
Major Geologic Storage Opportunities in California



Gas reservoir capacity: 1.7 Gt
Oil reservoir capacity: 3.6 Gt



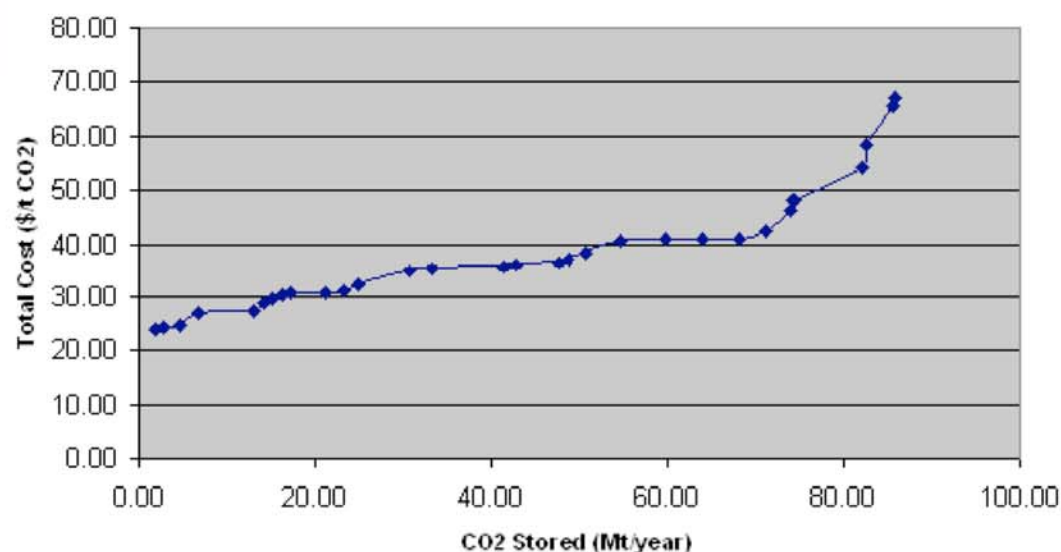
Additional Mapping of Key California Formations Aids Site Selection



Supply Curves for Geologic Storage Improve Cost Estimates

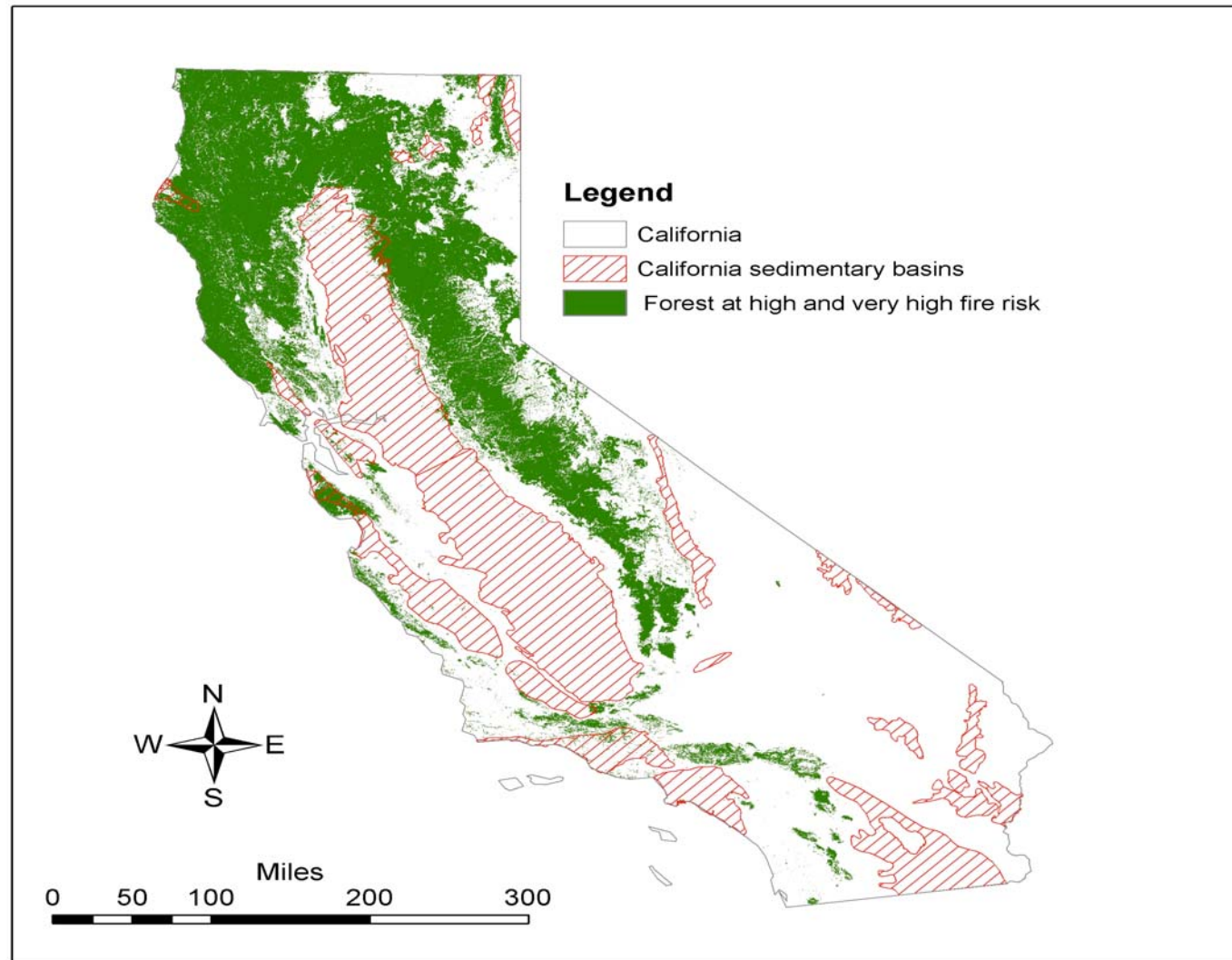
- CO₂ source characterization
- Capture cost estimation (about 80% of total cost)
- CO₂ storage capacity estimation
- Transportation cost estimation
- Source-sink matching

Marginal Cost Curve for California, Current Conditions



Matching sources to sinks
(Source: H. Herzog, MIT)

Linking Terrestrial and Geologic Sequestration



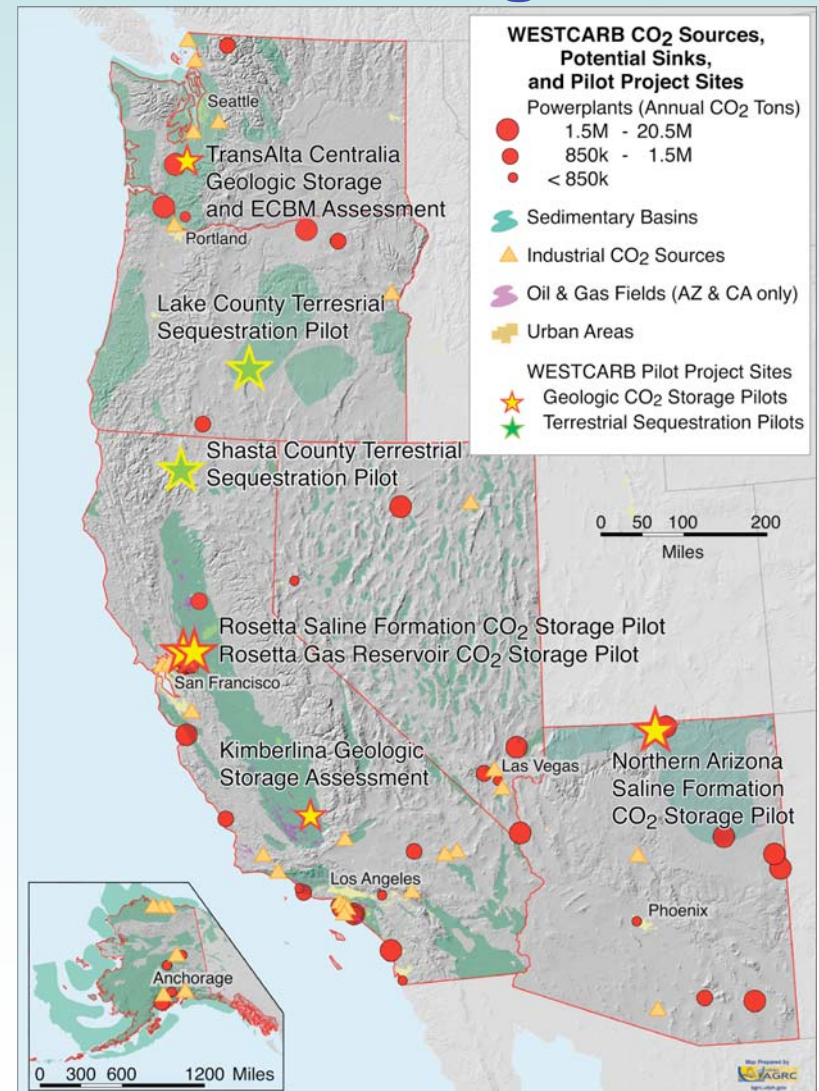
Public Awareness Continues to Grow—

- Climate change—related legislative initiatives becoming abundant in California and other western states
- Major reports recently issued—IPCC, MIT
- Media inquiries are increasing
- WESTCARB is meeting with state and local leaders
- Dedicated project website, www.westcarb.org

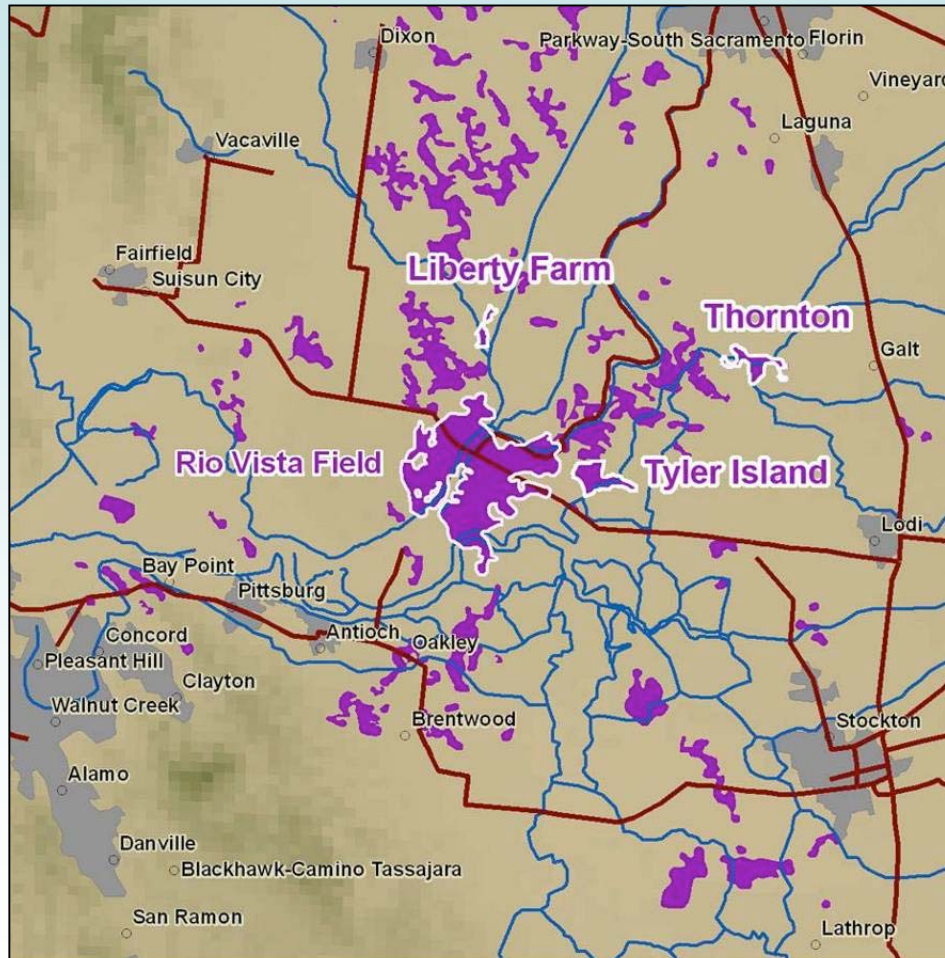


Pilot-Scale CO₂ Storage Projects Are Planned for Arizona, California, Oregon, and Washington

- Projects are representative of the best regional carbon sequestration options, both geologic and terrestrial
- Pilot projects involve site-specific focus for:
 - Testing injection technologies
 - Assessing storage capacity
 - Determining costs
 - Assessing leakage risks and demonstrating the effectiveness of safety measures
 - Validating monitoring methods
 - Establishing regulatory procedures



Rosetta Resources CO₂ Storage Pilot



Major Sacramento–San Joaquin River Delta natural gas fields shown in purple

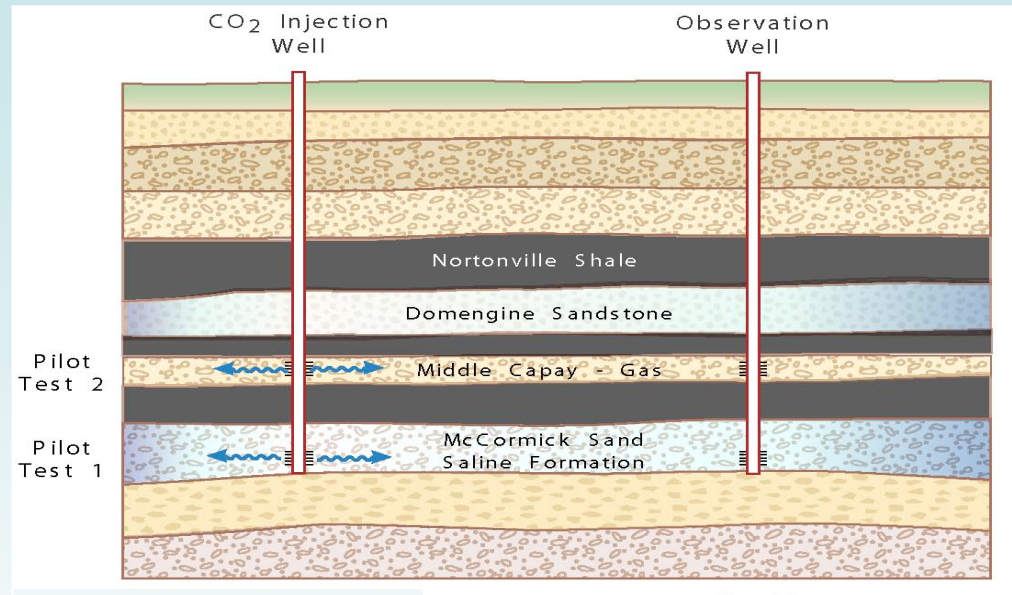
- Lead industrial partner: Rosetta Resources
- Validate sequestration potential of California Central Valley sediments
- Gain insight into viability of CO₂ Storage Enhanced Gas Recovery
- Inject up to 2000 tons at about 3400 ft depth
- Focus on monitoring

What Will This Pilot Test Accomplish?

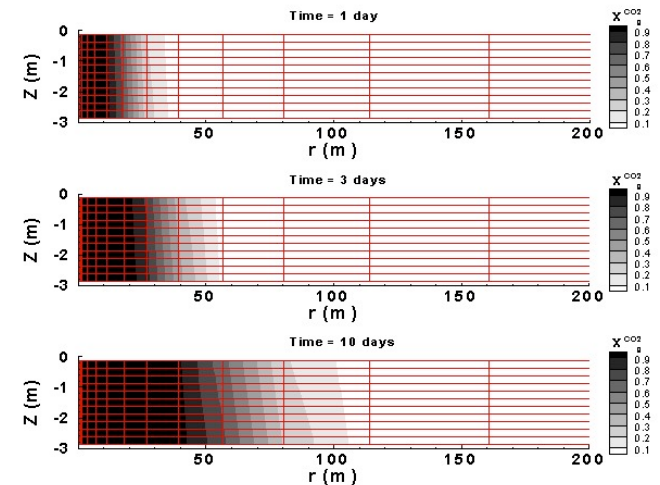
- CO₂ can be safely injected into deep subsurface geologic formations
- CO₂ can be securely stored by the geologic formations
- Computer models can predict how CO₂ will move into, and interact with, the reservoir rocks and fluids in the rock
- Multiple types of measurements can be used to monitor the CO₂ in the subsurface and detect leaks
- Help clarify state and federal regulatory framework, and other legal issues

Pilot Test Involves One Injection and One Observation Well

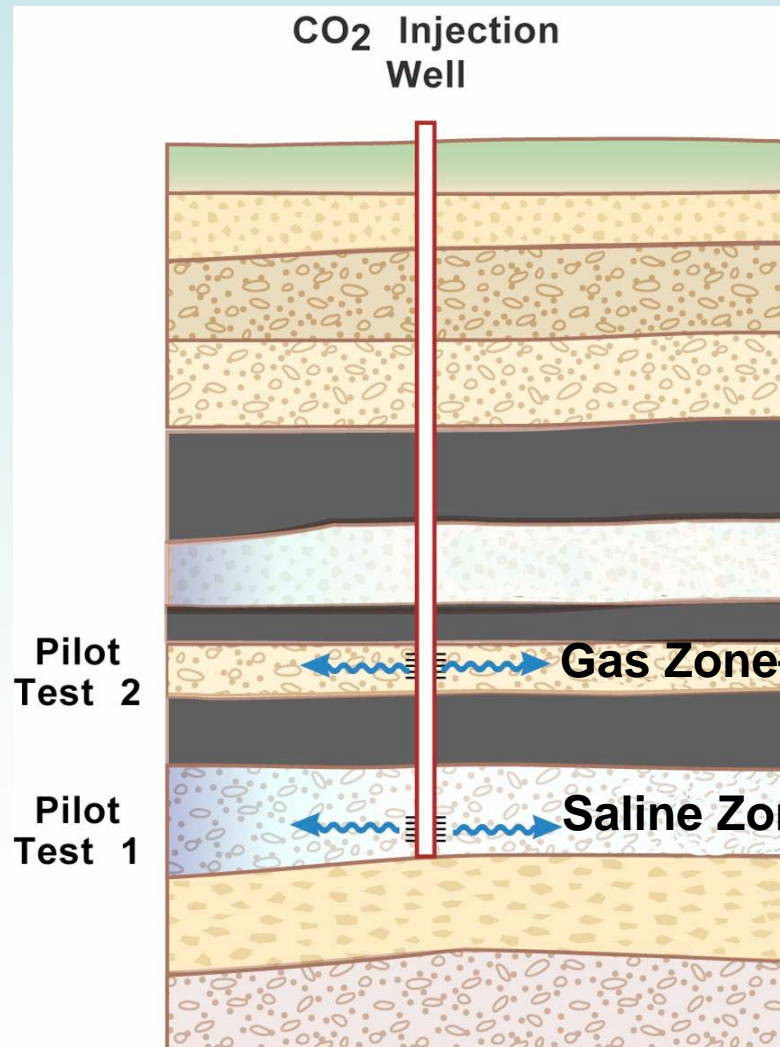
- Assess seal integrity, spatial extent of CO₂, storage capacity, injectivity
- Study mixing and CH₄ displacement in gas reservoir
- Measurements include downhole P and T, fluid sampling, wireline logging, vertical seismic profiling and cross-well seismic, and shallow groundwater and surface CO₂ sensors



Above: schematic cross-section; right: computer simulation of CO₂ in gas reservoir (R. Trautz, C. Oldenburg, LBNL)



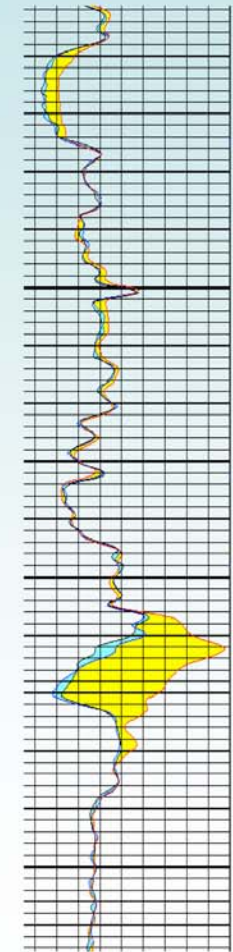
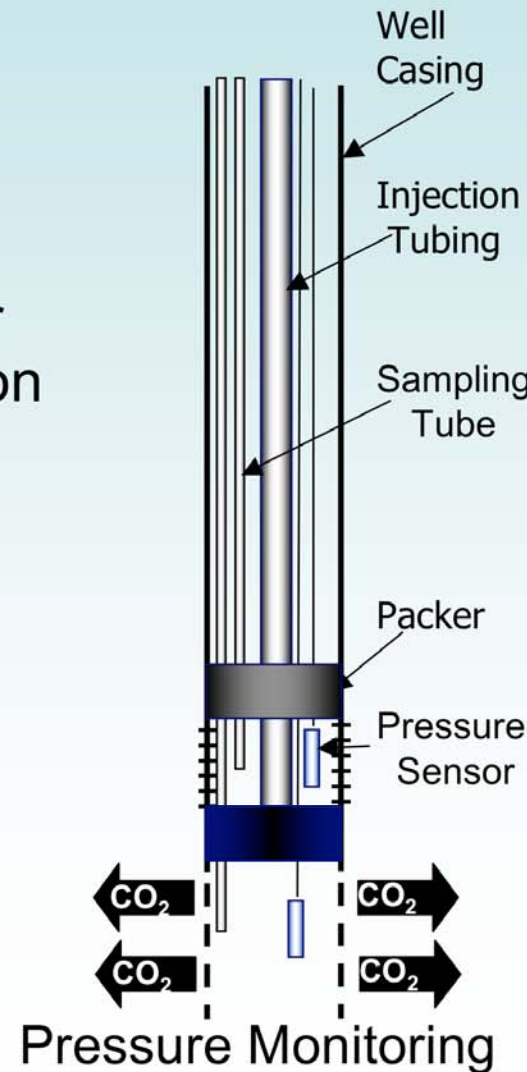
Pilot Tests Help Clarify Regulatory Framework



- California is an underground injection control (UIC) “mixed primacy” state
 - Both agencies have, in fact, been supportive
- Gas Zone—CA DOGGR (Short-term Injectivity Test)**
- Saline Zone—U.S. EPA Region 9 (UIC Class V)**

Pilot Tests Assess Geologic Seal Integrity

- Geomechanical analysis
 - Safe injection pressure
- Monitor pressure and water quality in a shallow formation above injection zone
- Obtain geophysical well logs from injection and observation wells before and after CO₂ injection



"RST" Log

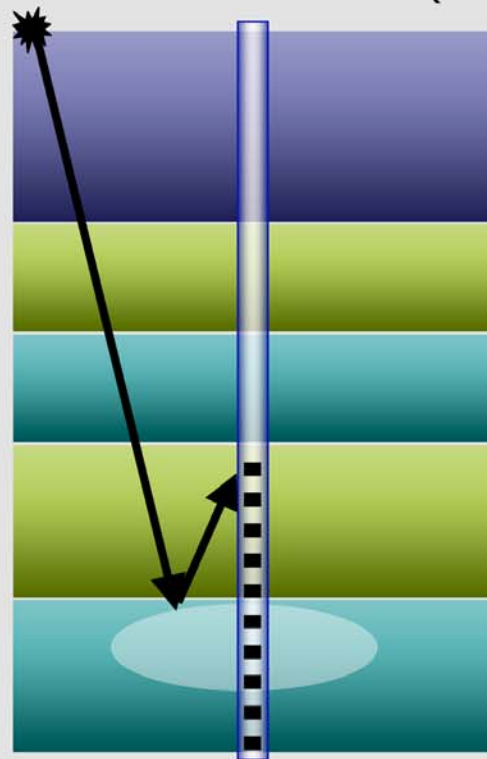
Pilot Tests Will Map the Spatial Extent of the Injected CO₂

- Seismic imaging

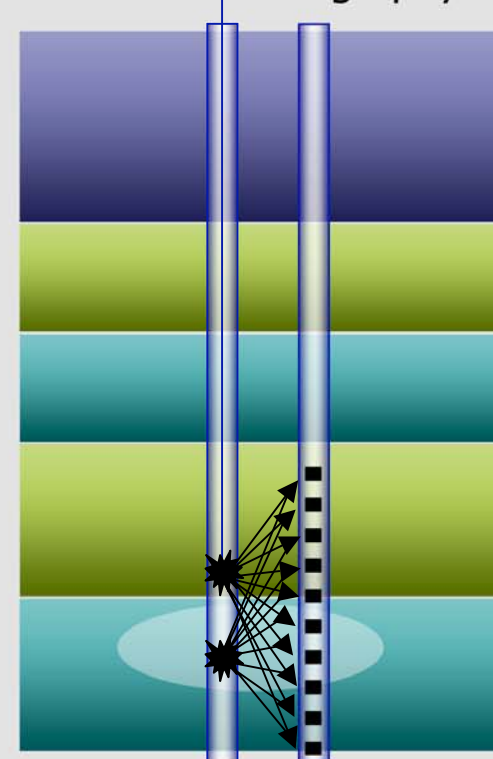
- Vertical seismic profiling (VSP)
- Cross-well seismic

- Fluid sampling

Vertical Seismic Profile (VSP)



Cross-Well Tomography

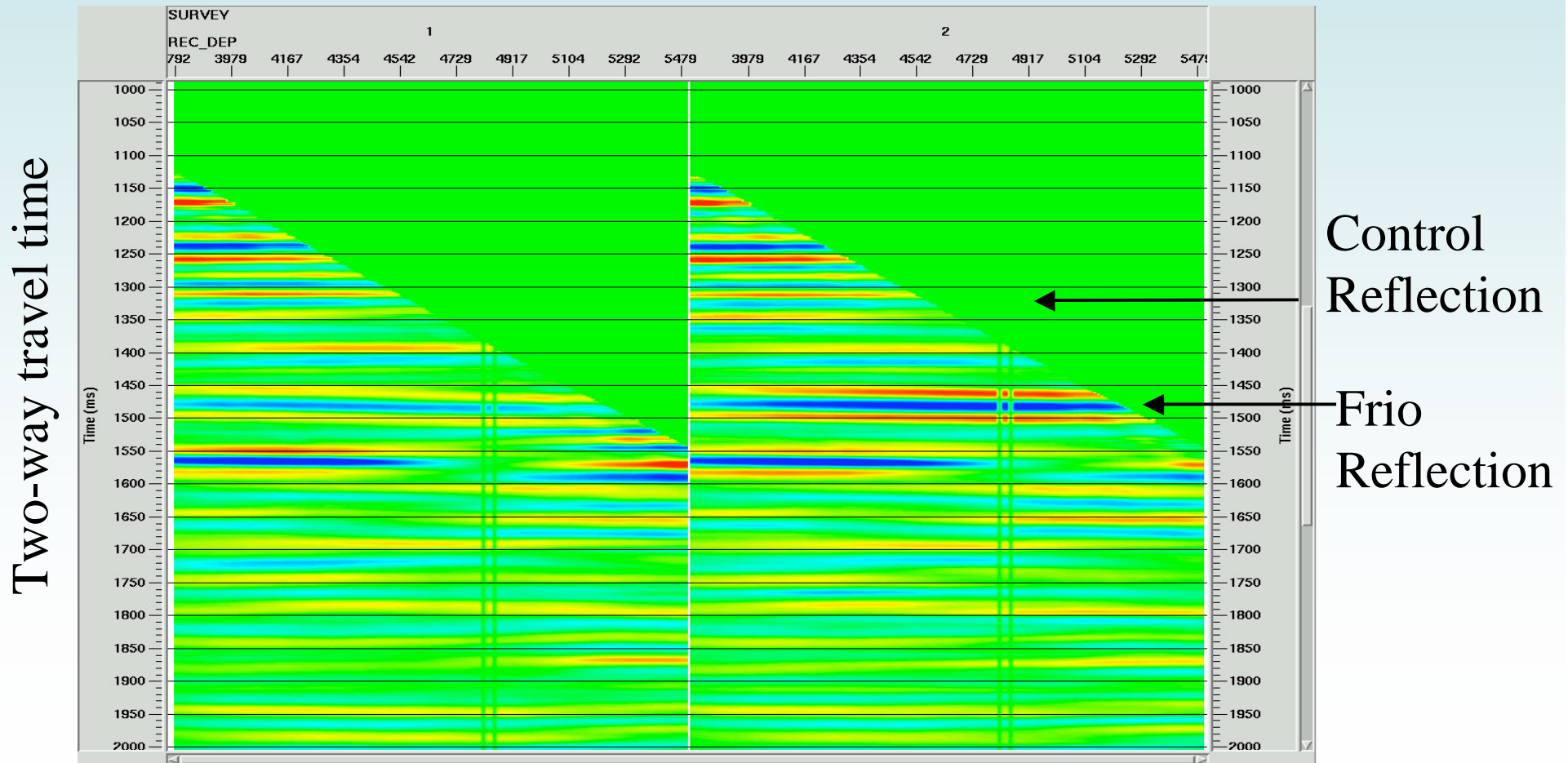


Prior Test Experience Demonstrates that Seismic Methods Can Show Location of the Injected CO₂

VSP Detection of 1600 ton injection in Saline Formation (Frio, Texas)

Pre Injection

Post Injection



(Daley, 2005)

Summary

- There are major opportunities for terrestrial and geologic CO₂ storage in California
- Linking terrestrial and geologic storage may provide unique approaches to addressing California mobile source emissions
- Public awareness of CCS has increased significantly; much more work to do
- Small-scale Phase II pilots are providing essential experience for regulatory clarification and project scale-up